TRANSFORMER PROBLEMS

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This bulletin is intended to present in condensed form the solution of many problems occurring in transformer operation on rural distribution systems. Acknowledgement is made to Lee M. Moore, F. B. Scott, and other engineers of the Rural Electrification Administration, to the General Electric Company and the Westinghouse Electric and Manufacturing Company for permission to reproduce drawings and other material, and to the engineers of numerous other manufacturing firms for their assistance, comments and suggestions in the preparation of this bulletin.

U. S. DEPARTMENT OF AGRICULTURE
RURAL ELECTRIFICATION ADMINISTRATION
TECHNICAL STANDARDS DIVISION

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TRANSFORMER PROBLEMS

I. POLARITY

The polarity of a single phase transformer is determined by the relative directions of the primary and secondary windings to the core. In complicated core and winding designs it is sometimes difficult to determine the polarity of the transformer directly from the direction of the windings. It therefore becomes necessary to set up a conventional system for the specification of polarity based on the arrangement of high and low voltage terminals on the transformer tank and on the direction of the induced voltages in the primary and secondary windings. It is important to remember that the relative directions of the induced voltage on both primary and secondary must be considered and not the direction of the impressed primary voltage.

Since the relative directions of the induced voltages as they appear at the transformer terminals depend on the order in which these terminals are considered, it becomes necessary to adopt some convention with respect to the order of consideration of the terminals. It is commonly accepted that the terminals of the high and low voltage windings are considered in the order in which they are brought out of the tank when the observer faces the tank from any one direction. To make this clear, refer to Figures 1a and 1b.

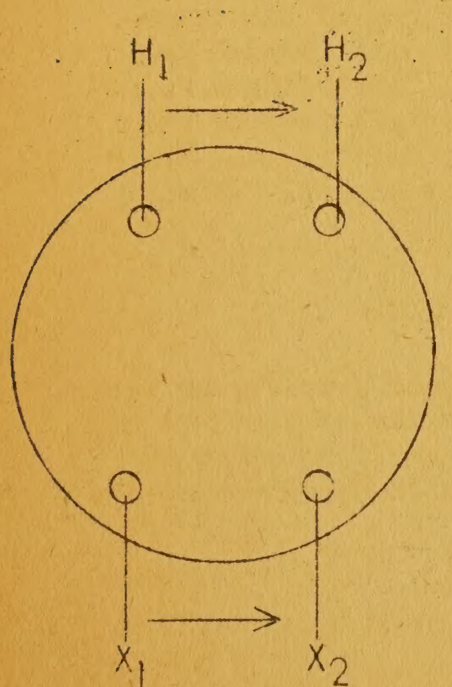


FIG. 1a

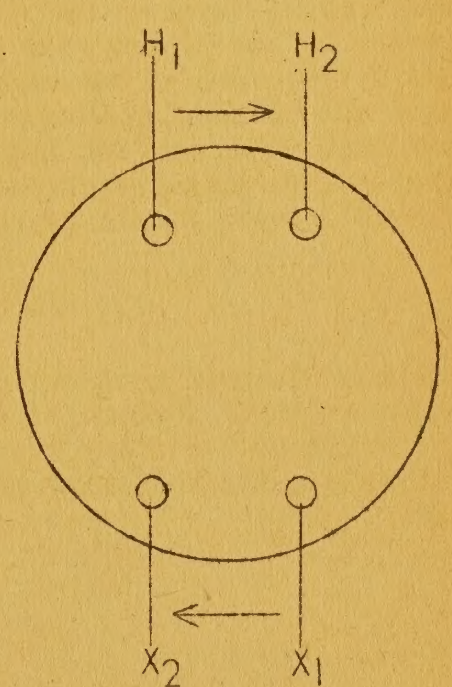


FIG. 1b

In these figures H_1 and H_2 represent the high voltage terminals, X_1 and X_2 the low voltage terminals. The arrows represent the directions of the induced voltages. Thus in Figure 1a, looking at the transformer tank from the low voltage side we see that the induced voltages are in the same directions in both windings. The polarity in this case is called "subtractive". The terminals are also numbered in this order, i.e., X_1 opposite H_1 and X_2 opposite H_2.

In Figure 2, the directions of the induced voltages are opposite and the terminals are numbered accordingly so that X_2 is opposite H_1 and X_1 opposite H_2. The polarity here is called "additive".

The reason for the terms "additive" and "subtractive" polarity become evident when the method of testing the polarity of a transformer is considered. Referring to Fig. 1b, if any two adjacent high and low-voltage terminals are connected together, such as, for example, H_1 and X_2 and voltage applied across either the primary or secondary windings, then the voltage measured between the free high and low voltage windings, H_2 and X_1 is the sum of the primary and secondary voltages. In the case of Figure 1a, if say, terminals H_1 and X_1 were connected and one winding excited the voltage across H_2 and X_2 would be the difference between the primary and secondary voltages. In making these tests only a small fraction of the rated voltage need be used for exciting the transformer.

When connecting transformers in parallel, or using special connections, great care must be taken in observing proper polarity. In the following connection diagrams, the <u>same</u> polarity is assumed for each transformer, whether additive or subtractive. If one of the transformers is not of the same polarity as the others, the connections must be reversed on one side of this transformer. According to proposed ASA standards, single phase distribution transformers of less than 8660 volts and 200 KVA shall have additive polarity. All other single phase transformers shall have subtractive polarity. In case of doubt, tests should be made.

II. SUBSTATION TRANSFORMER FAILURE

Most REA financed projects have delta-wye substation transformer banks. In the event of failure of one transformer, a portion of the load may be carried on the other two as an emergency measure if no spare is available. The following procedure is to be used in reconnecting the bank.

A. Substation Reconnections for a Delta-Wye Bank:

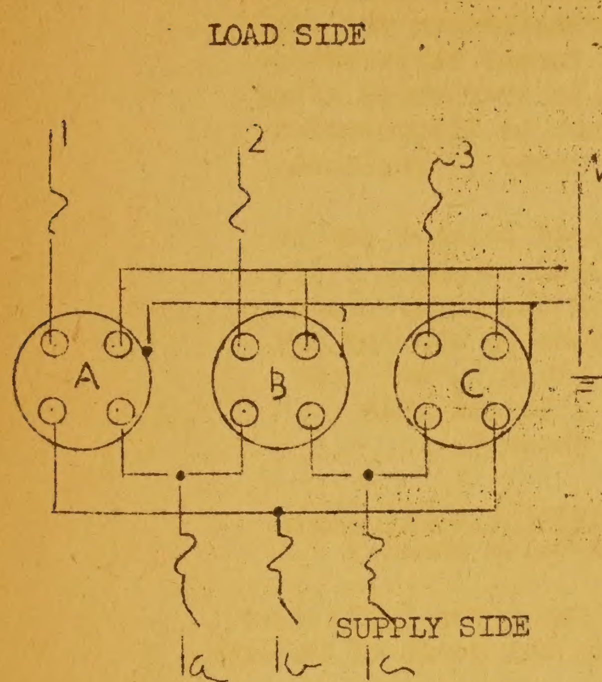


Figure 2. Before Failure

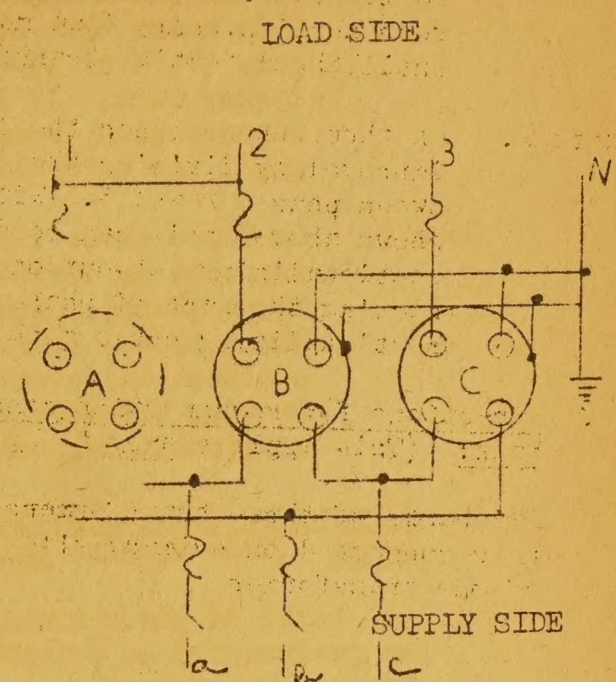


Figure 3. After Failure

Directions: (It is assumed that all 3 phase loads served by the line have been disconnected)

1. Open all disconnects or cut-outs on the supply and load sides of substation transformer bank, and ground the lines on the load side.

2. Disconnect all leads to transformer that failed.

3. Reconnect the phase wire on the Y side of the faulty transformer to phase two or three, selecting the one which is less loaded. This connection should be made so as to have the substation protected by the cut-out as before.

4. Make certain that no connections other than the ones specified above are changed on either supply or load side of the transformer bank.

5. Remove safety ground on the load side, and reclose supply side disconnects or cut-outs on the two good transformers, re-energizing transformer bank. Reclose load side cut-outs to energize the lines.

Note 1: The two-transformer bank can carry but 86.6% of the rated capacity of the two transformers. This means that the two transformers can carry only 57.8% of load of the former three-transformer bank. If the bank is overloaded after reconnection, some load must be disconnected until the defective transformer is replaced.

Note 2. On three phase lines the load balance can be improved by dividing the load on phase 1 between phases 2 and 3. With the connection shown above, this can be done by opening any sectionalizing cut-out on phase 1, and connecting the part of phase 1 beyond this sectionalizing cut-out to phase 3.

B. Directions for reconnecting consumer's three phase bank: (This applies only to Wye-Delta banks.)

All banks of three transformers for power loads must be reconnected on primary side in the event of failure of one transformer

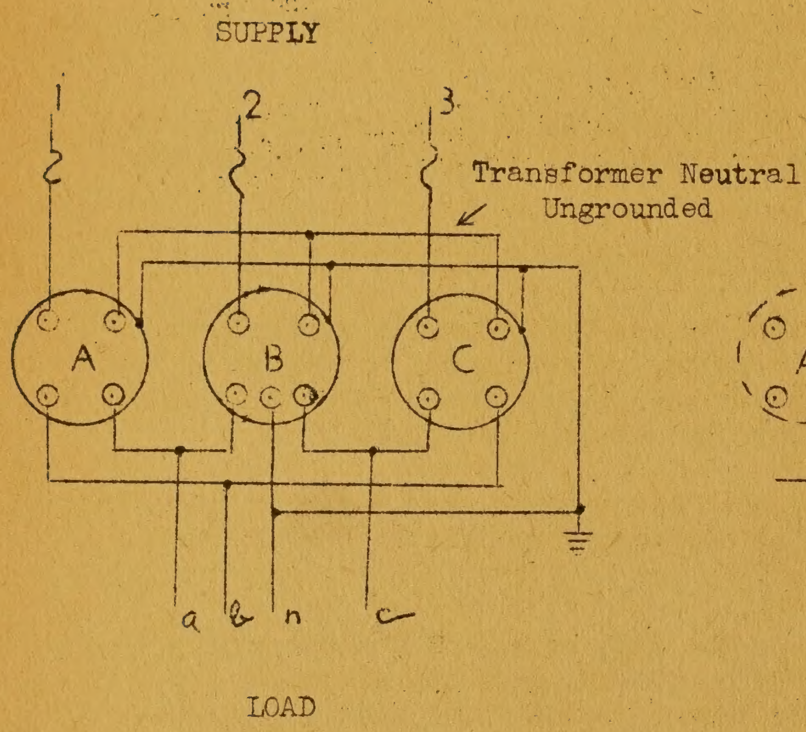


Figure 4
Three Phase Bank
Before failure of
Substation Transformer

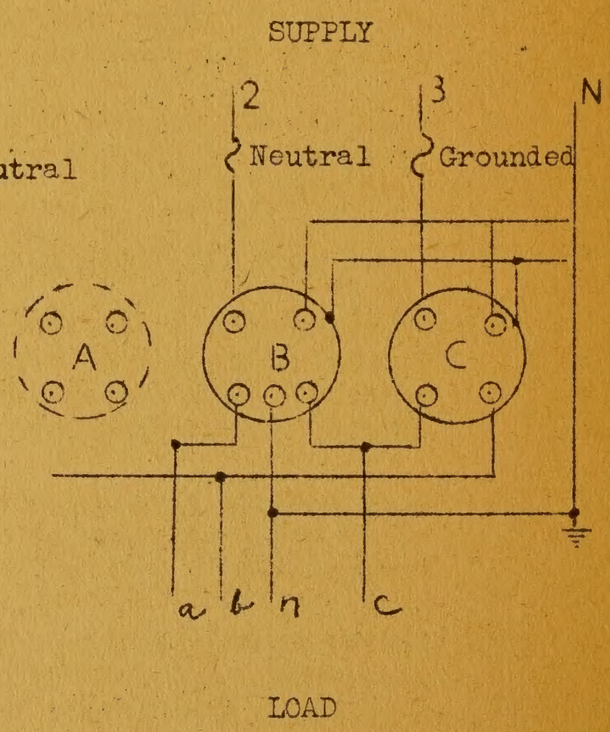


Figure 5
Three Phase Bank
After failure of
Substation transformer

1. Open cut-outs on all three phases on the primary side.
2. Disconnect, and remove from service, transformer A of the three transformers. The final connections are shown in Fig. 5. Phase 2 must not be connected to phase 3 at any point between the bank and the substation. Connect transformer neutral bus to ground.
3. Make certain that no other changes have been made to load side connections of transformers.
4. See Note 1, Fig. 6, Page 9.
5. Reclose cut-outs on the two transformers that are to remain in service.
6. Check voltage and phase rotation before leaving consumer's premises. Phase rotation may be checked by observing direction of rotation of unloaded polyphase motors.
7. If consumer has a V-bank (see Fig. 6), make certain that the two phase wires are not connected in parallel at any point.

III. PARALLELING TRANSFORMERS

For exact division of load in proportion to ratings, for transformers in parallel, the voltage ratings must be identical, the percentage impedances equal, and the ratio of resistance to reactance the same for both. Any other conditions involve division of load not in proportion to ratings, and may also cause circulating current to flow. Transformers may be operated in parallel when some of these conditions are not met, but with resultant loss in efficiency. One manufacturer makes the following recommendations:

"It is not considered good practice to operate transformers in parallel under the following conditions:

1. When the division of load is such that the load current flowing in any one is greater than 110% of its normal full load value, with a total load equal to the combined KVA rating.
2. When the no-load circulating current of any transformer exceeds 10% of the full load rated value.
3. When the arithmetical sum of the circulating and load currents is greater than 110% of the normal full load current.

"In the above, circulating current means the current flowing at no load exclusive of exciting current. By load current is meant the currents flowing under load, exclusive of exciting and circulating currents."

A. Unequal Voltage Ratio

The most important requirement is to have equal voltage ratings on each side for the transformers to be paralleled. If the voltage ratios are unequal, a circulating current results. For equal or nearly equal percent impedances and unequal ratios the following formula may be used to calculate the circulating current. It is exact where the ratios of resistance to reactance in the two transformers are equal, but also sufficiently accurate for most other cases.

$$\%I_{c1} = \frac{\%e\ (100)}{\%Z_1 + K\%Z_2} \qquad (1)$$

Where $\%I_{c1}$ = circulating current in percentage of the rated current of unit No. 1

$\%e$ = difference in voltage ratio expressed in percentage of normal

$\%Z_1$ = percent impedance of unit No. 1

$\%Z_2$ = percent impedance of unit No. 2

$K = \frac{KVA_1}{KVA_2}$

Example:

Two transformers of 5% impedance are connected in parallel in a single phase bank on a 7200 volt line, transformer 1 having a voltage ratio of 12,750/7200 and transformer 2 a ratio of 12750/7620. Capacity of transformer 1 is 100 KVA and of transformer 2 is 50 KVA.

Then: voltage ratio of transformer 1 = $\frac{12750}{7200} = 1.77$ (this is normal ratio)

voltage ratio of transformer 2 = $\frac{12750}{7620} = 1.68$

$$\%e = \frac{1.77 - 1.68}{1.77} \times 100 = 5.1\%$$

$$\%Z_1 = \%Z_2 = 5\%$$

$$K = \frac{Kva_1}{Kva_2} = \frac{100}{50} = 2$$

$$\%I_{c1} = \frac{5.1 \times 100}{5 + 2 \times 5} = 34\%$$

Such a parallel combination would obviously be unsuitable. In order to obtain the actual circulating current in amperes the rated current of transformer 1 is multiplied by I_{c1}. In the above example the rated current would be $I_1 = \frac{100,000}{7200} = 13.9$ amps. and $I_{c1} = 0.34 \times 13.9 = 4.7$ amps.

B. Unequal Percentage Impedances

For equal ratios, and unequal percentage impedances, the load division may be calculated approximately as follows:

Note: This method is exact when ratios between resistance and reactance of both transformers are equal.

$$I_1 = \frac{KVA_1/\%Z_1}{C} \times I_L \qquad (2)$$

$$I_2 = \frac{KVA_2/\%Z_2}{C} \times I_L \qquad (3)$$

Where $C = \frac{KVA_1}{\%Z_1} + \frac{KVA_2}{\%Z_2} + \dots$

I_L = Total load current

I_1 = Current No. 1

I_2 = Current No. 2

KVA_1 = Capacity of No. 1

KVA_2 = Capacity of No. 2

$\%Z_1$ = Percent impedance of transformer No. 1

$\%Z_2$ = Percent impedance of transformer No. 2

Example:

Assume two transformers with equal voltage ratios connected in parallel. Transformer 1 is of 100 Kva and 5% impedance. Transformer 2 is 50 Kva and 5.5% impedance. Total load current is 15 amperes.

$Kva_1 = 100$
$Kva_2 = 50$
$I_L = 15$ amperes
$\%Z_1 = 5$
$\%Z_2 = 5.5$

$$C = \frac{100}{5} + \frac{50}{5.5} = 29.1$$

$$I_1 = \frac{100/5}{29.1} \times 15 = 10.3 \text{ amperes}$$

$$I_2 = \frac{50/5.5}{29.1} \times 15 = 4.7 \text{ amperes}$$

If the line voltage is 7,200 volts, rated current for transformer 1 = $\frac{100,000}{7,200}$ = 13.9 amps and for transformer 2 = $\frac{50,000}{7,200}$ = 7 amps. Both transformers are therefore operating within the limits of rated capacity.

C. Unequal Ratios and Unequal Percent Impedances

Where both the voltage ratios and transformer impedances are different the circulating current due to off-ratio as calculated from A should be added to the load current in each transformer as calculated from B, to obtain the total current flowing in each transformer.

In many cases, resistance or reactance in the connections may unbalance parallel transformers. By properly adding the correct amount to the resistance and reactance in the leads, unbalanced transformers may be perfectly balanced.

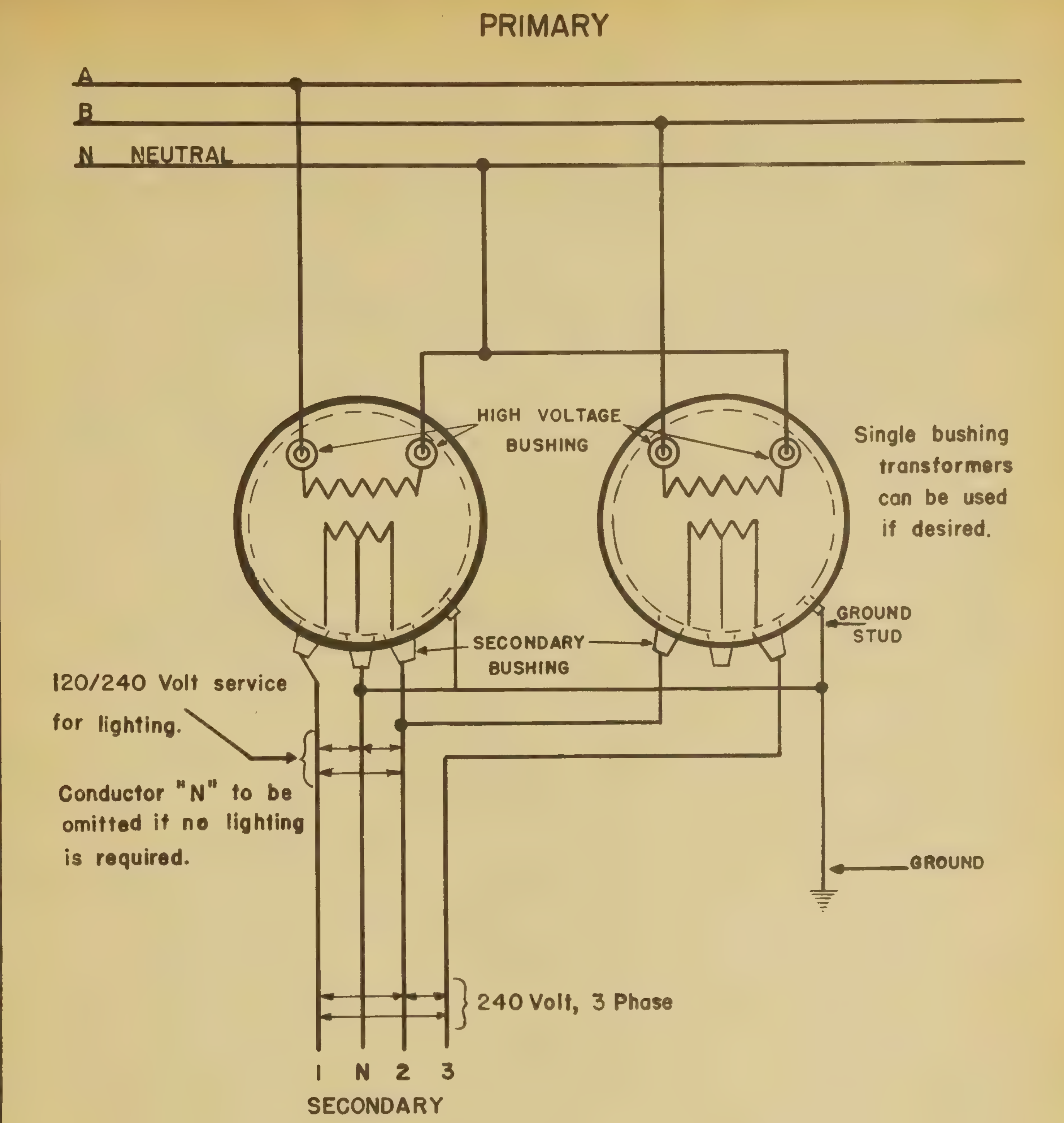
In connecting transformers in parallel, it is obviously important that the polarity of the voltages be carefully checked. After ascertaining the polarities of all transformers, a diagram of connections should be drawn before attempting any such work. If the transformers are connected in parallel with the reversed polarities large secondary circulating currents will result which will usually damage the transformers if not interrupted immediately.

IV. THREE PHASE SERVICE

Fig. 6 and Fig. 7 show the recommended connections for three phase service. Fig. 6 commonly called the "open-delta" or "V" connection should not be used in an excessive number of installations as it causes some unbalance on the system. Single bushing transformers may be used for the "V" connection, but if there is any possibility of placing these transformers in a bank of three, double bushing transformers should be obtained so that the connection shown in Fig. 7 can be used at a later date.

In the diagrams, all transformers are considered to be of the same polarity. If one is of unlike polarity, connections to it must be reversed, either on the primary or the secondary.

Where lines are sectionalized by means of single pole breakers, LINEMEN MUST BE CAREFUL TO THOROUGHLY GROUND AN OPEN LINE BEFORE WORKING ON IT. For example, in Fig. 7, if a breaker opened phase A on the source side of the three phase bank, phases B and C remaining energized, partial voltage might still exist on phase A beyond the' breaker, due to voltage and current relations in the three phase bank.



NOTE:

Combined capacity of two transformer should be 15.5% greater than combined capacity of three transformers △ or Y connected for the same load.

All internal connections from secondary coils to tanks must be removed.

A three-phase, four wire, delta meter must be used if conductor "N" is brought in.

Fig. 6	"V" CONNECTION WITH TWO TRANSFORMERS FOR THREE PHASE SERVICE	
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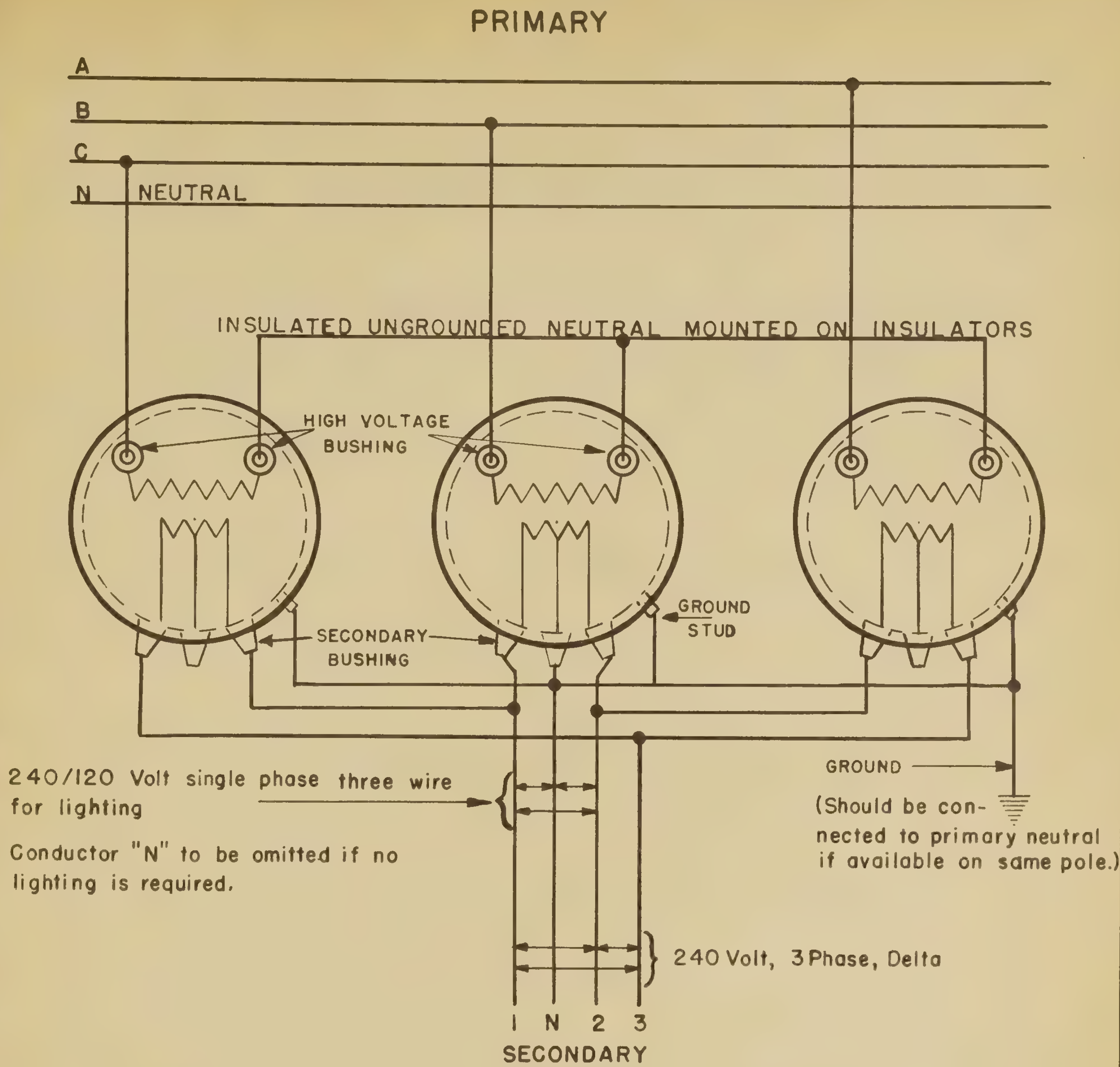


All internal connections from secondary coils to tank must be removed.

A three-phase, four wire, delta meter must be used if conductor "N" is brought in.

Fig. 7

12.5 KV PRIMARY 3 PHASE 4 WIRE Y - △
SCHEMATIC TRANSFORMER WIRING DIAGRAM

N. T. S.		DATE: 8/26/42
		A-2390

The amount of voltage on an open phase is variable, depending on many factors, but it may be as great as one-half the normal line-to-ground voltage. ALWAYS TREAT A LINE AS HOT UNTIL IT IS GROUNDED.

V. SINGLE PHASE LOAD ON THREE PHASE BANK

In many three phase transformer bank installations, it is also desired to serve some single phase load. Figs. 8, 9, and 10, copied by permission from "Transformer Engineering" by L. F. Blume (John Wiley & Sons, Inc.), give the limits of loads which may be served with various transformer combinations. The use of these curves can best be illustrated by examples.

Example 1:

Assume three transformers in a wye-delta bank rated as follows:

Transformer A - 15 KVA
Transformer B - 10 KVA
Transformer C - 10 KVA

The three phase load is 10 KVA at 80% power factor. What single phase load at unity power factor can be placed on transformer A without overloading any unit in the bank?

Solution: Use Fig. 9

The three phase KVA load in percent of transformer B rating in KVA $= \frac{10}{10}(100) = 100\%$.

Ratio of KVA_A to $KVA_B = \frac{15}{10} = 1.5$

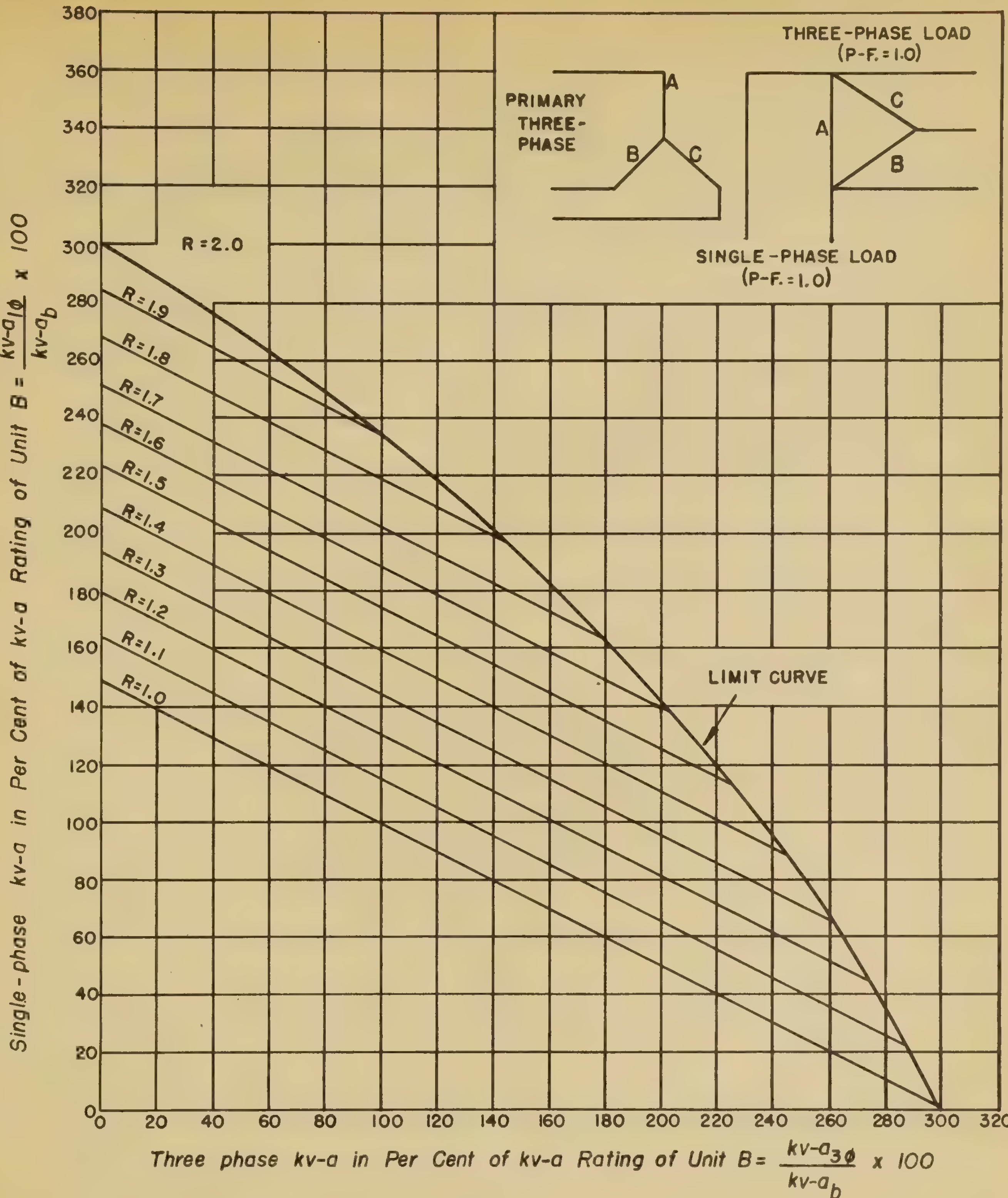
At 100% on the abscissa proceed vertically upward to the curve with R = 1.5. Then proceed horizontally and find that the single phase KVA in percent rating of unit B equals approximately 182%. Hence, additional allowable single phase load on A equals 1.82 (10) = 18.2 KVA.

If the three phase load were 20 KVA, the additional allowable single phase load on A would be found to be about 105% of transformer B rating or 10.5 KVA.

If the single phase load is known, the allowable three phase load may be found by the reverse process.

Example 2:

Given a three phase load of 20 KVA and a single phase load of 10 KVA, what transformer ratings should be used in a wye-delta bank?



Maximum Permissible Load on Isolated Y-Δ Transformer Bank having Three Single-phase Units A, B, and C. Three-phase Power Factor of 100 Per Cent.

$$Kv\text{-}a_b = Kv\text{-}a_c$$

$$R = \frac{Kv\text{-}a_a}{Kv\text{-}a_b}$$

Fig. 8

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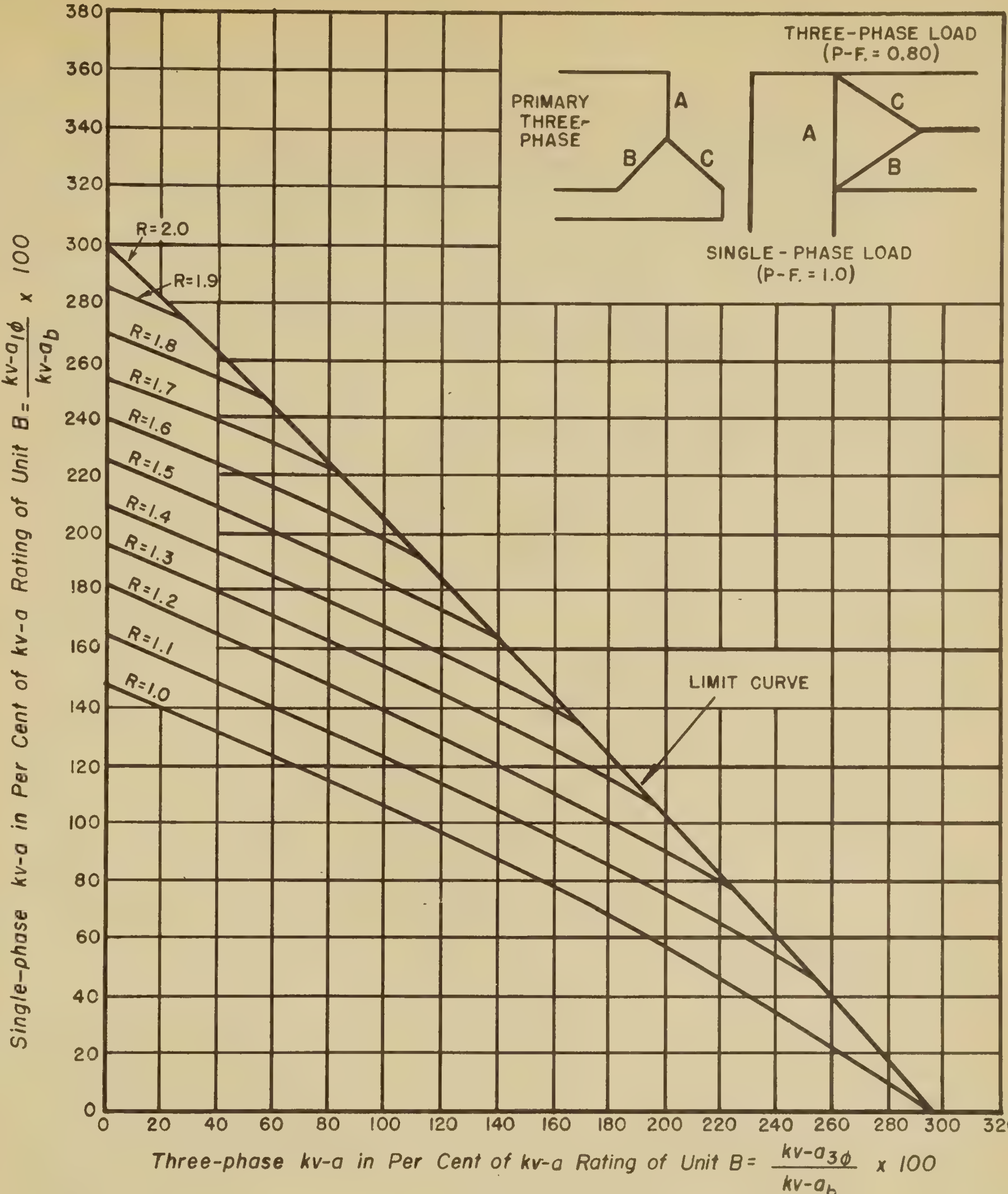

Maximum Permissible Load on Isolated Y-Δ Transformer Bank having Three Single-phase Units A, B and C. Three-phase Power Factor of 80 Per Cent.

$$Kv\text{-}a_b = Kv\text{-}a_c$$

$$R = \frac{Kv\text{-}a_a}{Kv\text{-}a_b}$$

Fig. 9

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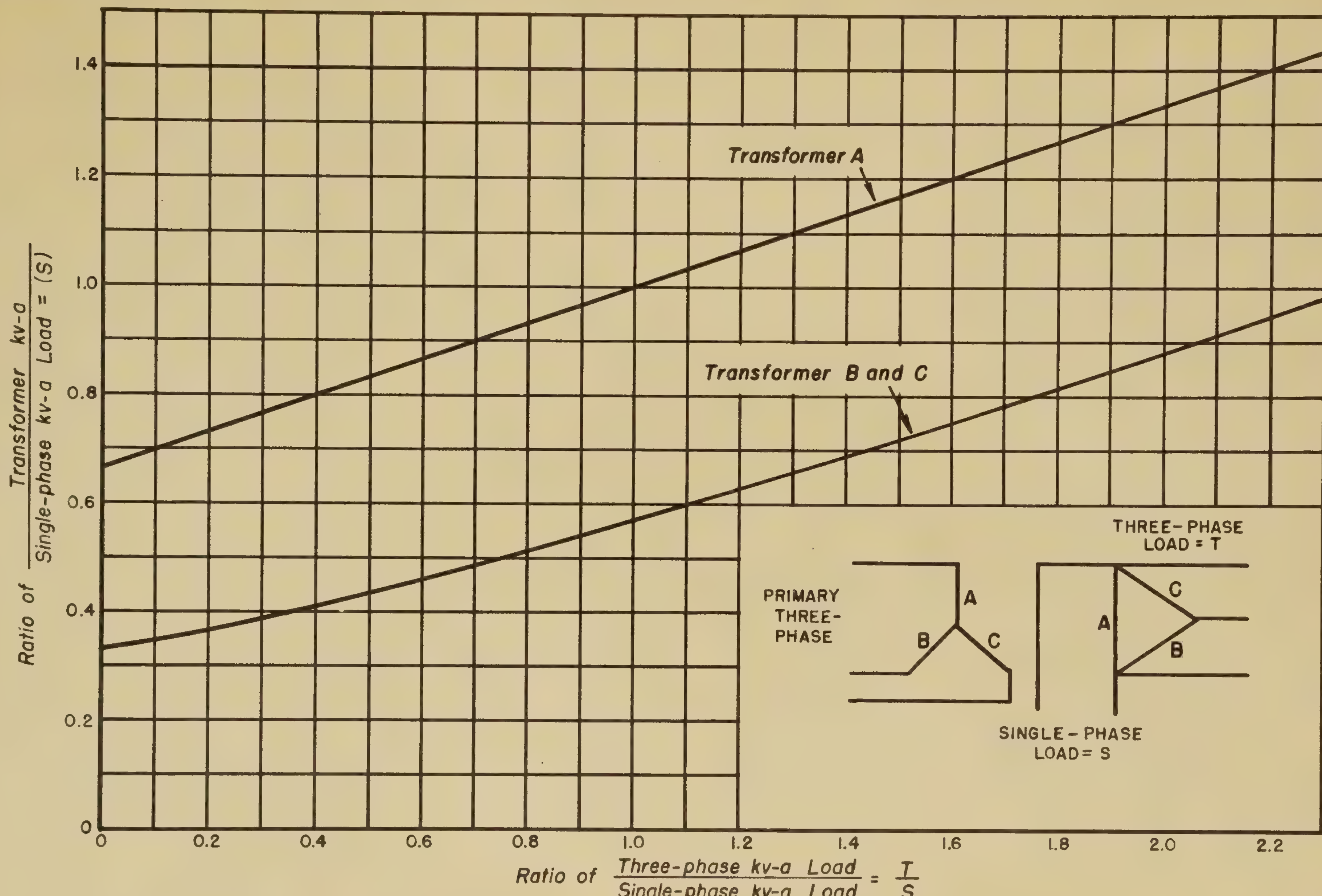


Transformer Capacity for Combined Single-phase and Three-phase Loads on Isolated Y-Δ Bank, with the Same Power Factor for Three-phase and Single-phase Loads. *Fig. 10*

Solution: Use Fig. 10.

Ratio of three phase load to single phase load $= \frac{T}{S} = 2.0$. In Fig. 10 on the abscissa find 2.0 and proceed vertically upward to the two curves. Proceeding horizontally from the transformer B and C curve, we find that the ratio of transformer KVA to single phase load KVA equals 0.87, and similarly from the transformer A curve, we find that the ratio of transformer KVA to single phase load KVA equals 1.33. Hence, transformers B and C should be rated at least 0.87 (10) = 8.7 KVA and transformer A should be rated at least 1.33 (10) = 13.3 KVA. The next larger standard ratings would be used, unless advantage were to be taken of the transformer overload capabilities.

VI. OVERLOADING OF TRANSFORMERS

A transformer may be overloaded during peak load conditions, providing light load follows and allows the transformer to cool off. According to the Interim Report on overloading transformers by the AIEE committee on electrical machinery (3): "For Daily Load Factors below 100 Per Cent, the loading may be increased 0.3 per cent for each per cent that the daily load factor is below 100 per cent, with normal life expectancy in no case should the overload permitted by this factor exceed 15%." (3).

In accordance with the committee's recommendations, the following table is suggested as a general guide for overloading transformers on REA systems. (If load curves of the system are available, Technical Standards Bulletin No. 1 (6) may be used for greater accuracy in estimating transformer overload capabilities.)

TABLE I

Permissible Transformer Overloads With No Reduction In Life Expectancy. A. I. E. E. Recommendations

Daily Average Ambient Temperature		Per Cent Rated Load On Self-Cooled Transformers	
		Daily Load Factor	
Degrees Centigrade	Degrees Fahrenheit	50% or less	60%
-10	14	155	152
0	32	145	142
10	50	135	132
15	59	130	127
20	68	125	122
25	77	120	117
30	86	115	112
35	95	105	102
40	104	95	92
45	113	85	82

The load factor is, of course, the ratio of the average load over a period to the peak load occurring in that period. This means that the peak load can be, say 115 percent of the transformer rating when operating on a system whose load factor is 50 percent in a 30 degree C ambient temperature. Although the load period on REA systems is usually taken as one month for purposes of other work, it is necessary that a one-day period be used in determining the load factor for calculating allowable overloads on transformers.

Short time overloads with some reduction in life expectancy are also given in the AIEE Interim Report mentioned above.

Transformers may also be safely overloaded continuously if forced-air blowers, oil-coolers, or water sprays are added. Any such installation requires detailed investigation and should be referred to the transformer manufacturer.

VII. TRANSFORMER PROTECTION

A. Short Circuit Protection and Service Distance

Transformers are protected by fuses or circuit breakers on the primary, on the secondary, or both. Technical Standards Bulletin #4 (5) outlines the procedure for calculating the required ratings of such devices for adequate protection of the transformer against short circuits. The rating of the required device depends on the transformer size, the service size, length, and number of wires, and characteristics of the device to be used. In addition, the device must coordinate with other devices on the system. Table II shows the protection afforded by various standard makes of secondary fuses to various sizes of transformers for 120 volt and 120/240 volt services. Table II is based on 3.5% transformer impedance, which is conservative, and gives the maximum service distance for which various makes and sizes of fuses will protect transformers against short circuits. If a particular make and size of fuse protects a certain size of transformer for a short circuit at a specified distance of service, the fuse will, of course, also protect the transformer for short circuit at any lesser service distance. In addition, the table gives the various household devices which will coordinate with these secondary fuses for a minimun service length of 100 feet. The use of the table can best be explained by examples.

Note on Use of Table II:

The first column gives service distances. The second and alternate even columns give corresponding maximum secondary fuse size which will give protection to the transformer for a secondary fault at this distance.

The third and odd columns (starred) give the house device which will coordinate at a minimun service distance of 100ft. with the corresponding secondary fuse. The household devices are listed

in order of slowness so that if a secondary fuse coordinates with #5, it will also coordinate with #4, 3, 2, and 1, and if it coordinates with #4, it will also coordinate with #3, 2, and 1, etc. In selecting the secondary fuse size, 30 ft. should be added for the length of the service entrance cable. In borderline cases, always select the <u>smaller</u> secondary fuse rating.

Example 1:

Given a transformer installation of 3 KVA with three No. 6 (120/240 volt) service conductors, using a Schweitzer & Conrad silver cartridge type SSI secondary fuse at the transformer, and 35 ampere "Quick Lag" breakers in the service entrance, what is the greatest possible service length which may be used with full protection afforded to the transformer against secondary short circuits, and still coordinate the secondary fuse with the service entrance breaker?

Solution:

Use the 3 KVA 3 wire transformer sheet. In the SSI column under Number 6 service, it can be seen that a service length up to 2000 feet may be used with a 40 ampere SSI S&C fuse, a service length up to 1400 feet may be used with a 50 ampere fuse, and a service length up to 900 feet may be used with a 60 ampere fuse. Any of these fuses will coordinate with the service entrance breaker specified for any service length beyond 100 feet. Hence, a minimum distance of 100 feet and a maximum distance of 900, 1400, or 2000 feet depending on the secondary fuse size may be used for the service in this particular case.

Example 2:

Given, transformer installation of 5 KVA with a 3 wire, Number 4 service and a service distance up to 500 feet. The service entrance protection is a 60 ampere fuse. What size General Electric catalogue 9F13A secondary fuse will protect the transformers?

Solution:

Going to the 5 KVA 3 wire sheet, on the 500 foot row for #4 Service and under the GE1 column, it can be seen that a 95 ampere secondary fuse will do the job. However, since the 60 amp service entrance fuse will also cooordinate with the 85 ampere secondary fuse, the 85 ampere secondary fuse may be used for more conservative protection if desired. It is usually preferable to use the smallest secondary device which will still coordinate with the service entrance protection.

Table II is based on characteristics furnished by the various manufacturers in 1942. The table is intended only as a guide, and special cases should be worked out by the system engineer.

Table III shows the maximum service distances which may be used with one type of transformer with internal and secondary breaker so as to obtain protection against secondary short circuits. Table III is based on A.S.A. Permissible Emergency overload curves and transformer manufacturer's data on the secondary breaker characteristics.

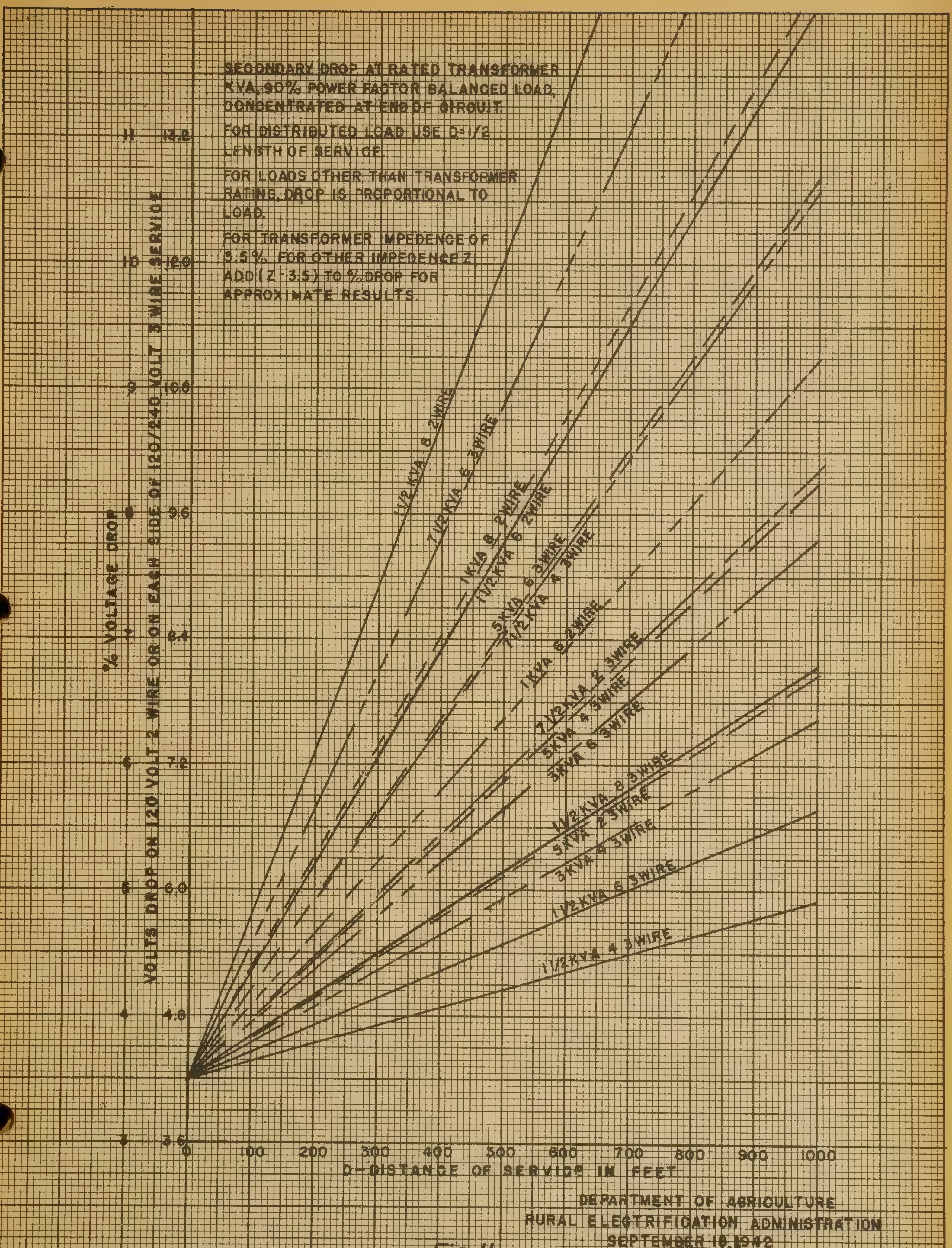
The service distance may not only be limited by the transformer protective problem, but may also be limited by the voltage drop. Fig. 11 gives the voltage drops to be expected for various transformer sizes and services. The drop including the transformer and service should be added to the existing or anticipated primary drop to obtain the total drop at the load. This drop should be within the required limits in order to provide adequate service. The selected service distance should be the lesser of the two figures given by the fault current protective and voltage drop requirements.

Transformer primary fusing schedules may be calculated in the same manner as the secondary fusing tables. Unfortunately, experience has shown that for the smaller sizes of distribution transformers on 7200 volt lines, the primary fuse size required to provide protection against secondary faults is so small that it is frequently blown by lightning surges, or damaged by mechanical vibration. Hence, primary fuse ratings in use on REA systems have been increased since 1936. The present recommended primary transformer fuse ratings and the maximum service distances for which protection may be provided against secondary short circuits for transformer impedance of 3.5% are shown in Table IV. The large variation in fuses made by different manufacturers is readily apparent.

Although distribution transformers of less than 10 KVA will usually have an impedance of less than 3.5%, and the primary fuse will therefore provide greater protection than shown, it can be seen that, in the main, little protection against secondary troubles is furnished by such primary fuse ratings. Smaller ratings will offer more protection, but at the same time more false fuse blowings can be expected. Since the transformer failure rate has been small on REA systems, the trend has been toward the higher fuse ratings.

B. Lightning Protection

Transformers are protected by arresters, expulsion tubes or open gaps. The function of such devices is to limit the voltage drop between the transformer windings and between windings and ground to a value, as far as practicable below that at which the insulation will fail. In order to hold the transformer tank, the mid-



SECONDARY DROP AT RATED TRANSFORMER KVA, 90% POWER FACTOR BALANCED LOAD, CONCENTRATED AT END OF CIRCUIT.
FOR DISTRIBUTED LOAD USE D=1/2 LENGTH OF SERVICE.
FOR LOADS OTHER THAN TRANSFORMER RATING, DROP IS PROPORTIONAL TO LOAD.
FOR TRANSFORMER IMPEDENCE OF 3.5%. FOR OTHER IMPEDENCE Z, ADD (Z-3.5) TO % DROP FOR APPROXIMATE RESULTS.
% VOLTAGE DROP
VOLTS DROP ON 120 VOLT 2 WIRE OR ON EACH SIDE OF 120/240 VOLT 3 WIRE SERVICE
D-DISTANCE OF SERVICE IN FEET
1 1/2 KVA 8 2 WIRE
1 1/2 KVA 6 3 WIRE
1 KVA 8 2 WIRE
1 1/2 KVA 6 2 WIRE
3 KVA 6 3 WIRE
1 1/2 KVA 4 3 WIRE
1 KVA 6 2 WIRE
1 1/2 KVA 2 3 WIRE
5 KVA 4 3 WIRE
3 KVA 6 3 WIRE
1 1/2 KVA 8 3 WIRE
3 KVA 2 3 WIRE
3 KVA 4 3 WIRE
1 1/2 KVA 6 3 WIRE
1 1/2 KVA 4 3 WIRE
DEPARTMENT OF AGRICULTURE
RURAL ELECTRIFICATION ADMINISTRATION
SEPTEMBER 16, 1942

Fig. 11

Table II Protection Afforded by Secondary Fuses of Various Makes To 1 KVA Transformer With 2 Wire 120 Volt Service Sheet 1

Service Dist.	M1 *	M2 *	GE1 *	GE2 *	LM *	SS1 *	SS2 *	K *	SC1 *	SC2 *	SC3 *	B *
Number 8 Service												
100												
125												
150	60 3	75 3	75 4	75 4	50 4	40 4	100 4	60 4	50 4	50 4	40 4	25 4
175	60 3	50 3	50 3	75 4	50 4	40 4	100 4	60 4	50 4	50 4	40 4	25 4
200	60 3	50 3	50 3	75 4	50 4	40 4	100 4	60 4	50 4	50 4	40 4	25 3
300	60 3	50 3	50 3	50 3	50 4	40 4	75 4	60 4	50 4	50 4	40 4	20 3
400	50 3	50 3	50 3	50 3	40 3	40 4	75 4	50 4	50 4	40 4	30 4	20 3
500	50 3	50 3	45 3	45 3	40 3	40 4	75 4	50 4	40 4	30 3	30 4	20 3
600	50 3	45 1	45 3	45 3	40 3	40 4	60 3	40 3	30 3	30 3	25 3	15 3
700	40 1	45 1	45 3	45 3	40 3	40 4	60 3	40 3	30 3	30 3	25 3	15 3
800	40 1	40 1	40 3	40 3	30 2	30 4	60 3	40 3	30 3	20 3	25 3	15 3
900	40 1	40 1	40 3	40 3	30 2	30 4	60 3	40 3	30 3	20 3	25 3	15 3
1000	40 1	40 1	40 3	40 3	30 2	30 4	50 3	30 3	30 3	20 3	25 3	15 3
1200	40 1	30	40 3	30 1	30 2	30 4	40 3	30 3	25 3	20 3	20 3	15 3
1400	30 1	30	30 1	30 1	25 1	30 4	40 3	30 3	25 3	20 3	15 2	15 3
1600	25	25	25 1	25 1	25 1	30 4	40 3	25 3	20 3	20 3	15 2	15 3
1800	25	25	25 1	25 1	25 1	30 4	30 2	25 3	15 1	20 3	15 2	15 3
2000	20	25	20 1	25 1	25 1	25 4	30 2	20 1	15 1	15 1	15 2	15 3
Number 6 Service												
100												
125												
150	75 4	75 3	75 4	75 4	50 4	50 4	100 4	60 4	60 4	50 4	40 4	25 4
175	75 4	75 3	75 4	75 4	50 4	50 4	100 4	60 4	60 4	50 4	40 4	25 4
200	75 4	75 3	75 4	75 4	50 4	50 4	100 4	60 4	60 4	50 4	40 4	25 4
300	60 3	75 3	75 4	75 4	50 4	40 4	100 4	60 4	60 4	50 4	40 4	25 4
400	60 3	50 3	50 3	50 3	50 4	40 4	100 4	60 4	50 4	50 4	40 4	25 4
500	50 3	50 3	50 3	50 3	50 4	40 4	75 4	50 4	50 4	50 4	30 4	20 3
600	50 3	50 3	50 3	50 3	40 3	40 4	75 4	50 4	50 4	40 4	30 4	20 3
700	50 3	50 3	45 3	45 3	40 3	40 4	75 4	50 4	40 4	40 4	30 4	20 3
800	50 3	50 3	45 3	45 3	40 3	40 4	75 4	50 4	40 4	30 3	30 4	20 3
900	50 3	45 1	45 3	45 3	40 3	40 4	75 4	40 3	40 4	30 3	25 3	15 3
1000	40 1	45 1	45 3	45 3	40 3	40 4	60 3	40 3	30 3	30 3	25 3	15 3
1200	40 1	40 1	40 3	40 3	30 2	30 4	60 3	40 3	30 3	20 3	25 3	15 3
1400	40 1	40 1	40 3	40 3	30 2	30 4	60 3	30 3	30 3	20 3	25 3	15 3
1600	40 1	40 1	30 1	40 3	30 2	30 4	50 3	30 3	25 3	20 3	25 3	15 3
1800	40 1	30	30 1	30 1	30 2	30 4	40 3	25 3	25 3	20 3	20 3	15 3
2000	30 1	30	30 1	30 1	25 1	30 4	40 3	25 3	20 3	20 3	15 2	15 3

Legend:

M1-Matthews Cartridge Type C.T.S.
M2-Matthews Fuse Link Series 50H and 100H below 100 amps. Series 100B above 100 amps.
GE1-Gen. Elec. Cartridge Catalog 9F13A
GE2-Gen. Elec. Fuse Links Type 9F1S
LM-Line Material Unifit (Cartridge and Link)
SS1-Southern States Cartridge Type S.F.L.
SS2-Southern States Cartridge Type S.X.L.
K-Kearney "Tubular" Cartridge
SC1-Schweitzer & Conrad Silver Cart. Type SSI
SC2-Schweitzer & Conrad Tin Cart. Type STI
SC3-Schweitzer & Conrad Tin Link Series 88,000
B-Bussman Type JLS Cartridge or JPX Link

*
1 15 Amp Fusetat
2 15 Amp Circuit Breaker (Quick-lag or Heineman magnetic)
3 30 Amp Fuse
4 25 Amp Multi-breaker

Table II Protection Afforded by Secondary Fuses of Various Makes To $1\frac{1}{2}$ KVA Transformer With 2 Wire 120 Volt Service

Service Dist	M1*	M2*	GE1*	GE2*	LM*	SS1*	SS2 *	K *	SC1*	SC2 *	SC3*	B *
					Number 8 Service							
100												
125												
150	75 3	85 3	85 4	85 4	75 4	60 4	150 4	100 4	75 4	50 3	65 4	35 4
175	75 3	85 3	85 4	85 4	60 4	60 4	150 4	75 4	75 4	50 3	50 4	35 4
200	75 3	85 3	85 4	85 4	60 4	60 4	125 4	75 4	60 4	50 3	50 4	35 4
300	75 3	75 3	75 3	75 3	60 4	60 4	125 4	75 4	60 4	50 3	40 4	30 3
400	60 3	50 1	50 3	75 3	50 3	60 4	100 4	60 3	60 4	40 3	40 4	30 3
500	60 3	50 1	50 3	50 3	50 3	60 4	75 3	60 3	50 3	40 3	40 4	25 3
600	50 1	50 1	50 3	50 3	40 3	50 4	75 3	50 3	40 3	40 3	30 3	25 3
700	50 1	45 1	45 2	45 3	40 3	50 4	75 3	50 3	40 3	40 3	30 3	25 3
800	50 1	45 1	45 2	45 3	40 3	50 4	60 3	40 3	30 3	30 3	30 3	25 3
900	40 1	45 1	45 2	40 3	40 3	50 4	60 3	40 3	30 3	30 3	25 3	20 3
1000	40 1	40	40 2	40 3	30 1	40 4	60 3	40 3	30 3	30 3	25 3	20 3
1200	30	40	40 2	40 3	30 1	40 4	50 3	30 3	25 3	25 3	20 3	20 3
1400	30	30	30 1	30 1	30 1	40 4	40 3	30 3	25 3	25 3	20 3	20 3
1600	30	30	30 1	30 1	30 1	30 3	40 3	25 2	25 3	20 2	15 1	20 3
1800	25	25	25 1	30 1	25 1	30 3	30 1	25 2	25 3	20 2	15 1	15 1
2000	25	25	25 1	25	25 1	25 3	30 1	25 2	25 3	15 1	15 1	15 1
					Number 6 Service							
100												
125												
150	100 4	95 4	85 4	75 4	75 4	60 4	150 4	100 4	75 4	50 3	65 4	35 4
175	100 4	95 4	85 4	75 4	75 4	60 4	150 4	100 4	75 4	50 3	65 4	35 4
200	100 4	95 4	85 4	75 4	75 4	60 4	150 4	100 4	75 4	50 3	65 4	35 4
300	75 3	85 3	85 4	75 4	60 4	60 4	125 4	75 4	75 4	50 3	65 4	35 4
400	75 3	85 3	75 3	50 3	60 4	60 4	125 4	75 4	60 4	50 3	50 4	30 3
500	60 3	75 3	75 3	50 3	60 4	60 4	100 4	75 4	60 4	50 3	40 4	30 3
600	60 3	50 1	50 3	50 3	50 3	60 4	100 4	60 3	60 4	40 3	40 4	30 3
700	60 3	50 1	50 3	50 3	50 3	60 4	100 4	60 3	50 3	40 3	40 4	25 3
800	60 3	50 1	50 3	45 3	50 3	50 4	75 3	50 3	50 3	40 3	30 3	25 3
900	60 3	50 1	50 3	45 3	40 3	50 4	75 3	50 3	50 3	40 3	30 3	25 3
1000	50 1	45 1	45 2	45 3	40 3	50 4	75 3	50 3	50 3	40 3	30 3	25 3
1200	50 1	45 1	45 2	45 3	40 3	50 4	75 3	50 3	40 3	30 3	30 3	25 3
1400	40 1	45 1	40 2	40 3	40 3	50 4	60 3	40 3	40 3	30 3	30 3	20 3
1600	40 1	40	40 2	40 3	30 1	40 4	60 3	40 3	30 3	30 3	25 3	20 3
1800	30	30	30 1	30 1	30 1	40 4	50 3	30 3	30 3	25 3	20 3	20 3
2000	30	30	30 1	30 1	30 1	40 4	40 3	30 3	25 3	25 3	20 3	20 3

Legend:

M1-Matthews Cartridge Type C.T.S.
M2-Matthews Fuse Link Series 50 H and 100 H below 100 amps. Series 100B above 100 amps.
GE1-Gen. Elec. Cartridge Catalog 9F13A
GE2-Gen. Elec. Fuse Links Type 9F1S
LM-Line Material Unifit (Cartridge and link)
SS1-Southern States Cartridge Type S.F.L.
SS2-Southern States Cartridge Type S.X.L.
K-Kearney "Tubular" Cartridge
SC1-Schweitzer & Conrad Silver Cart. Type SS1
SC2-Schweitzer & Conrad Tin Cart. Type STI
SC3-Schweitzer & Conrad Tin Link Series 88,000
B-Bussman Type JLS Cartridge or JPX Link

*
1 20 Amp Fusetat
2 30 Amp Fuse
3 20 Amp Circuit Breaker (Quicklag or Heinemann magnetic)
4 35 Amp Multi-breaker

Table II Protection Afforded by Secondary Fuses of Various Makes To $1\frac{1}{2}$ KVA Transformer With 3 Wire 120/240 Volt Service   Sheet 3

Service Dist.	M1 *	M2*	GE1 *	GE2*	LM *	SS1*	SS2*	K *	SC1*	SC2 *	SC3 *	B *
						Number 8 Service						
100												
125												
150	75 4	50 2	50 3	75 5	50 3	30 4	75 3	50 3	50 4	40 3	30 3	20 3
175	75 4	50 2	50 3	75 5	50 3	30 4	75 3	50 3	50 4	40 3	30 3	20 3
200	60 3	50 2	50 3	75 5	40 3	30 4	75 3	50 3	50 4	40 3	30 3	20 3
300	60 3	50 2	50 3	50 3	40 3	30 4	75 3	50 3	50 4	40 3	30 3	15 3
400	50 2	50 2	45 3	45 3	40 3	30 4	75 3	50 3	40 3	30 3	30 3	15 3
500	50 2	45 1	45 3	45 3	40 3	30 4	75 3	50 3	40 3	30 3	30 3	15 3
600	50 2	45 1	45 3	45 3	40 3	30 4	60 3	40 3	30 3	30 3	25 3	15 3
700	40 2	45 1	40 2	45 3	30 1	30 4	60 3	40 3	30 3	30 3	25 3	15 3
800	40 1	40	40 2	45 3	30 1	30 4	60 3	30 3	30 3	25 3	25 3	12 2
900	40 1	40	40 2	40 2	30 1	30 4	50 3	30 3	30 3	25 3	20 3	12 2
1000	30	40	30 1	40 2	30 1	30 4	50 3	30 3	25 3	25 3	20 3	12 2
1200	30	30	30 1	30 1	30 1	30 4	40 3	25 2	25 3	20 2	20 3	12 2
1400	25	25	25 1	30 1	25 1	25 3	40 3	25 2	20 2	20 2	15 2	12 2
1600	25	25	25 1	30 1	25 1	25 3	30 2	20 1	20 2	15 1	15 2	12 2
1800	25	25	25 1	25 1	20 1	25 3	30 2	20 1	15 1	15 1	15 2	12 2
2000	25	25	20	25 1	20 1	25 3	30 2	15 1	15 1	15 1	10 1	12 2
						Number 6 Service						
100												
125												
150	75 4	50 2	50 3	75 5	50 3	40 5	75 3	60 4	60 5	40 3	40 5	20 3
175	75 4	50 2	50 3	75 5	50 3	40 5	75 3	60 4	60 5	40 3	40 5	20 3
200	75 4	50 2	50 3	75 5	50 3	40 5	75 3	60 4	50 4	40 3	40 5	20 3
300	60 3	50 2	50 3	75 5	40 3	30 4	75 3	50 3	50 4	40 3	30 3	20 3
400	60 3	50 2	50 3	50 3	40 3	30 4	75 3	50 3	50 4	40 3	30 3	20 3
500	60 3	50 2	50 3	50 3	40 3	30 4	75 3	50 3	50 4	40 3	30 3	15 3
600	60 3	50 2	50 3	50 3	40 3	30 4	75 3	50 3	40 3	40 3	30 3	15 3
700	50 2	45 1	45 3	50 3	40 3	30 4	75 3	50 3	40 3	30 3	30 3	15 3
800	50 2	45 1	45 3	45 3	40 3	30 4	75 3	40 3	40 3	30 3	25 3	15 3
900	50 2	45 1	45 3	45 3	40 3	30 4	75 3	40 3	40 3	30 3	25 3	15 3
1000	40 1	45 1	45 3	45 3	40 3	30 4	60 3	40 3	30 3	30 3	25 3	15 3
1200	40 1	40	40 2	45 3	40 3	30 4	60 3	40 3	30 3	25 3	25 3	12 2
1400	40 1	40	40 2	40 2	40 3	30 4	50 3	30 3	30 3	25 3	20 3	12 2
1600	30	40	30 1	40 2	30 1	30 4	50 3	30 3	25 3	25 3	20 3	12 2
1800	30	30	30 1	30 1	30 1	30 4	50 3	25 2	25 3	20 2	20 3	12 2
2000	30	30	30 1	30 1	25 1	25 3	40 3	25 2	20 2	20 2	15 2	12 2

Legend:

M1-Matthews Cartridge Type C.T.S.
M2-Matthews Fuse Link Series 50H and 100H below 100 amps. Series 100B above 100 amps.
GE1-Gen. Elect. Cartridge Catalog 9F13 A
GE2-Gen. Elec. Fuse Links Type 9F1S
LM-Line Material Unifit (Cartridge and Link)
SS1-Southern States Cartridge Type S.F.L.
SS2-Southern States Cartridge Type S.X.L.
K-Kearney "Tubular" Cartridge
SC1-Schweitzer & Conrad Silver Cart. Type SSI
SC2-Schweitzer & Conrad Tin Cart. Type STI
SC3-Schweitzer & Conrad Tin Link Series 88,000
B-Bussman Type JLS Cartridge or JPX Link

*
1 20 Amp. Fusetat
2 30 Amp Fuse
3 20 Amp Circuit Breaker (Quicklag or Heinemann magnetic)
4 60 Amp Fuse
5 35 Amp Multi-breaker

Table II Protection Afforded by Secondary Fuses of Various Makes To 3 KVA Transformers With 3 Wire 120/240 Volt Service

Sheet 4

Service Dist.	M1*	M2*	GE1 *	GE2*	LM *	SS1*	SS2*	K *	SC1*	SC2*	SC3 *	B *
					Number 6 Service							
100												
125												
150	100 4	100 4	95 5	95 5	75 4	60 5	150 5	100 5	100 5	75 5	65 5	40 4
175	100 4	100 4	85 4	95 5	75 4	60 5	150 5	100 5	100 5	75 5	65 5	40 4
200	100 4	100 4	85 4	95 5	75 4	60 5	150 5	100 5	100 5	75 5	65 5	40 4
300	100 4	95 4	85 4	95 5	75 4	60 5	150 5	100 5	75 4	75 5	65 5	35 4
400	75 3	85 4	85 4	85 5	75 4	60 5	150 5	75 4	75 4	60 4	50 4	35 4
500	75 3	85 4	75 3	75 4	60 4	60 5	125 4	75 4	75 4	60 4	50 4	30 3
600	75 3	75 2	75 3	75 4	60 4	60 5	125 4	75 4	60 4	60 4	40 4	30 3
700	60 2	50	75 3	75 4	50 3	60 5	100 4	60 4	60 4	50 4	40 4	30 3
800	60 2	50	50 2	75 4	50 3	60 5	100 4	60 4	60 4	50 4	40 4	25 2
900	60 2	50	50 2	75 4	50 3	60 5	75 4	60 4	50 4	50 4	40 4	25 2
1000	50 2	50	50 2	50 2	40 2	50 4	75 4	50 3	40 4	50 4	30 3	25 2
1200	50 2	45	45 2	50 2	40 2	50 4	75 4	50 3	40 4	40 3	30 3	25 2
1400	50 2	45	45 2	45 2	40 2	50 4	60 2	40 2	30 3	30 2	30 3	25 2
1600	40	45	40 2	40 2	30 2	40 4	60 2	40 2	30 3	30 2	25 2	20 1
1800	40	40	40 2	40 2	30 2	40 4	60 2	40 2	30 3	30 2	25 2	20 1
2000	40	40	30	40 2	30 2	40 4	50 2	30 2	20 2	20 2	25 2	20 1
					Number 4 Service							
100												
125												
150	100 4	100 4	95 5	100 5	75 4	75 5	150 5	100 5	100 5	75 5	80 5	40 4
175	100 4	100 4	95 5	100 5	75 4	75 5	150 5	100 5	100 5	75 5	80 5	40 4
200	100 4	100 4	95 5	100 5	75 4	75 5	150 5	100 5	100 5	75 5	80 5	40 4
300	100 4	100 4	95 5	95 5	75 4	60 5	150 5	100 5	75 4	75 5	65 5	40 4
400	100 4	95 4	85 4	95 5	75 4	60 5	150 5	100 5	75 4	75 5	65 5	40 4
500	100 4	95 4	85 4	85 5	75 4	60 5	150 5	75 4	75 4	75 5	65 5	35 4
600	75 3	85 4	85 4	85 5	75 4	60 5	150 5	75 4	75 4	60 4	65 5	35 4
700	75 3	85 4	85 4	85 5	60 4	60 5	125 4	75 4	75 4	60 4	50 4	35 4
800	75 3	85 4	75 3	75 4	60 4	60 5	125 4	75 4	75 4	60 4	50 4	30 3
900	75 3	75 2	75 3	75 4	60 4	60 5	125 4	75 4	75 4	60 4	50 4	30 3
1000	60 2	75 2	75 3	75 4	50 3	60 5	100 4	60 4	60 4	50 4	40 4	30 3
1200	60 2	50	50 2	75 4	50 3	60 5	100 4	60 4	60 4	50 4	40 4	25 2
1400	60 2	50	50 2	75 4	50 3	50 5	75 4	60 4	50 4	50 4	40 4	25 2
1600	50 2	50	50 2	50 2	40 2	50 5	75 4	50 3	40 3	40 3	30 3	25 2
1800	50 2	45	45 2	50 2	40 2	50 5	75 4	50 3	40 3	40 3	30 3	25 2
2000	50 2	45	45 2	45 2	40 2	50 5	75 4	50 3	40 3	30 2	30 3	25 2

Legend:

M1-Matthews Cartridge Type C.T.S.
M2-Matthews Fuse Link Series 50H and 100H below 100 amps. Series 100B above 100 amps.
GE1-Gen. Elec. Cartridge Catalog 9F13A
GE2-Gen. Elec. Fuse Links Type 9F1S
LM-Line Material Unifit (Cartridge and Link)
SS1-Southern States Cartridge Type S.F.L.
SS2-Southern States Cartridge Type S.X.L.
K-Kearney "Tubular" cartridge
SC1-Schweitzer & Conrad Silver Cart. Type SSI
SC2-Schweitzer & Conrad Tin Cart. Type STI
SC3-Schweitzer & Conrad Tin Link Series 88,000
B-Bussman Type JIS Cartridge or JPX Link

*
1 30 Amp Fusetat
2 30 Amp Fuse
3 35 Amp Circuit Breaker (Quick lag or Heinemann magnetic)
4 60 Amp Fuse
5 50 Multi-breaker

Table II Protection Afforded by Secondary Fuses of Various Makes To 5 KVA Transformer With 3 Wire 120/240 volt Service

Service Dist.	M1*	M2 *	GE1*	GE2*	LM*	SS1*	SS2 *	K *	SC1*	SC2 *	SC3 *	B *
	Number 6 Service											
100												
125												
150	150 4	125 2	125 4	100 4	100 4	100 4	150 4	150 4	150 4	125 4	100 4	60 4
175	150 4	125 2	100 4	100 4	100 4	100 4	150 4	150 4	125 4	125 4	100 4	60 4
200	150 4	125 2	100 4	100 4	100 4	100 4	150 4	150 4	125 4	125 4	100 4	60 4
300	125 3	100 2	100 4	100 4	85 4	100 4	150 4	125 4	100 4	100 4	80 4	50 3
400	100 2	95 1	95 3	95 4	85 4	100 4	150 4	100 4	100 4	75 3	65 4	50 3
500	100 2	95 1	85 2	85 3	75 3	75 4	150 4	100 4	75 4	75 3	65 4	50 3
600	75 1	85	85 2	85 3	75 3	75 4	150 4	75 3	75 4	75 3	65 4	40 3
700	75 1	75	75 2	75 2	60 2	75 4	125 3	75 3	75 4	60 2	50 3	40 3
800	60	50	75 2	75 2	60 2	75 4	100 2	75 3	60 3	60 2	50 3	40 3
900	60	50	75 2	75 2	50 1	75 4	100 2	60 2	60 3	60 2	40 2	40 3
1000	60	50	50	50 1	50 1	75 4	100 2	60 2	50 2	50 2	40 2	40 3
1200	50	45	50	50 1	50 1	75 4	75 2	60 2	40 2	50 2	40 2	35 2
1400	50	45	45	45	40	60 4	75 2	50 1	40 1	40 1	30 2	35 2
1600	50	45	45	45	40	60 4	60 1	50 1	30	30 1	30 2	35 2
1800	50	40	40	40	40	60 4	60 1	40	30	30 1	30 2	30 1
2000	50	40	40	40	40	50 4	50	40	30	30	30 2	30 1
	Number 4 Service											
100												
125												
150	200 4	125 2	125 4	100 4	100 4	125 4	150 4	150 4	150 4	125 4	100 4	60 4
175	150 4	125 2	125 4	100 4	100 4	100 4	150 4	150 4	150 4	125 4	100 4	60 4
200	150 4	125 2	125 4	100 4	100 4	100 4	150 4	150 4	150 4	125 4	100 4	60 4
300	150 4	125 2	100 4	100 4	100 4	100 4	150 4	150 4	125 4	125 4	100 4	60 4
400	125 3	100 2	100 4	100 4	85 4	100 4	150 4	125 4	125 4	100 4	80 4	50 3
500	125 3	100 2	95 3	95 4	85 4	100 4	150 4	100 4	100 4	100 4	80 4	50 3
600	100 2	95 1	95 3	95 4	85 4	100 4	150 4	100 4	100 4	75 3	65 4	50 3
700	100 2	95 1	85 2	95 4	85 4	100 4	150 4	100 4	75 4	75 3	65 4	50 3
800	100 2	95 1	85 2	85 3	75 3	75 4	150 4	100 4	75 4	75 3	65 4	50 3
900	75 1	85	85 2	85 3	75 3	75 4	150 4	75 3	75 4	75 3	65 4	40 3
1000	75 1	85	85 2	85 3	60 2	75 4	125 3	75 3	75 4	60 2	50 3	40 3
1200	75 1	75	75 2	75 2	60 2	75 4	125 3	75 3	60 3	60 2	50 3	40 3
1400	60	50	75 2	75 1	60 2	75 4	100 2	60 2	60 3	60 2	50 3	40 3
1600	60	45	50	50 1	50 1	75 4	100 2	60 2	50 2	60 2	40 2	40 3
1800	60	45	50	50 1	50 1	75 4	75 2	60 2	50 2	60 2	40 2	35 2
2000	50	45	50	45	40	60 4	75 2	50 1	40 1	60 2	30 2	35 2

Legend:

M1-Matthews Cartridge Type C.T. S.
M2-Matthews Fuse Link Series 50H and 100H below 100 amps. Series 100B above 100 amps.
GE1-Gen. Elec. Cartridge Catalog 9F13A
GE2-Gen. Elec. Fuse Links Type 9F1S
LM-Line Material Unifit (Cartridge and Link)
SS1-Southern States Cartridge Type S.F.L.
SS2-Southern States Cartridge Type S.X.L.
K-Kearney "Tubular" Cartridge
SC1-Schweitzer & Conrad Silver Cart. Type SS1
SC2-Schweitzer & Conrad Tin Cart. Type STI
SC3-Schweitzer & Conrad Tin Link Series 88,000
B-Bussman Type JLS Cartridge or JPX Link

*
1 35 Amp Circuit Breaker (quic lag or Heinemann magnetic)
2 60 Amp Fuse
3 35 Amp Fusetron
4 50 Amp Multi-Breaker

Table II Protection Afforded by Secondary Fuses of Various Makes To $7\frac{1}{2}$ KVA Transformer With 3 Wire 120/240 Volt Service

Sheet 6

Service Dist.	M1 *	M2*	GE1 *	GE2*	LM *	SS1*	SS2*	K *	SC1*	SC2 *	SC3*	B *
Number 6 Service												
100												
125												
150	200 4	125 4	125 4	100 4	100 4	150 4	150 4	175 4	150 4	150 4	100 3	100 4
175	150 4	125 4	125 4	100 4	100 4	150 4	150 4	175 4	150 4	150 4	100 3	75 4
200	150 4	125 4	125 4	100 4	100 4	150 4	150 4	175 4	150 4	150 4	100 3	75 4
300	150 4	100 3	100 4	100 4	100 4	150 4	150 4	150 4	150 4	125 4	80 3	60 4
400	125 3	100 3	100 4	100 4	85 4	125 4	150 4	125 4	100 4	100 4	80 3	60 4
500	100 3	95 2	95 3	95 4	85 4	125 4	150 4	100 4	100 4	75 3	80 3	50 3
600	75 1	95 2	85 2	85 3	75 3	125 4	150 4	100 4	75 4	75 3	65 3	50 3
700	75 1	85 1	85 2	85 3	75 3	100 4	150 4	75 3	75 4	75 3	65 3	50 3
800	75 1	85 1	85 2	75 2	75 3	100 4	125 4	75 3	75 4	60 3	65 3	50 3
900	75 1	75	75 2	75 2	60 3	100 4	125 4	75 3	60 3	60 3	50 3	50 3
1000	60	75	75 2	75 2	60 3	100 4	100 3	75 3	60 3	60 3	50 3	50 3
1200	50	50	50	50 1	60 3	75 4	75 2	60 2	50 3	50 2	40 3	50 3
1400	50	50	50	50 1	50 1	50 4	75 2	60 2	40 1	50 2	40 3	40 3
1600	50	45	50	40	50 1	50 4	75 2	50 1	30	50 2	40 3	40 3
1800	40	45	40	40	50 1	50 4	60 1	50 1	30	30	30 2	35 2
2000	40	40	40	40	50 1	50 4	50	40	30	30	30 2	35 2
Number 4 Service												
100												
125												
150	200 4	125 4	150 4	100 4	150 4	150 4	150 4	200 4	200 4	200 4	100 4	100 4
175	200 4	125 4	150 4	100 4	150 4	150 4	150 4	200 4	200 4	200 4	100 4	100 4
200	200 4	125 4	125 4	100 4	150 4	150 4	150 4	175 4	200 4	150 4	100 4	100 4
300	150 4	125 4	125 4	100 4	100 4	150 4	150 4	175 4	150 4	150 4	100 4	75 4
400	150 4	125 4	100 4	100 4	100 4	150 4	150 4	150 4	150 4	125 4	100 4	75 4
500	125 3	100 3	100 4	100 4	100 4	125 4	150 4	125 4	125 4	125 4	80 4	60 4
600	125 3	100 3	100 4	100 4	85 4	125 4	150 4	125 4	100 4	100 4	80 4	60 4
700	100 3	100 3	95 3	95 4	85 4	125 4	150 4	100 4	100 4	100 4	80 4	60 4
800	100 3	95 2	95 3	95 4	85 4	125 4	150 4	100 4	100 4	75 3	65 4	50 3
900	100 3	95 2	85 2	85 3	75 3	125 4	150 4	100 4	100 4	75 3	65 4	50 3
1000	75 1	85 1	85 2	85 3	75 3	100 4	150 4	100 4	75 4	75 3	65 4	50 3
1200	75 1	85 1	85 2	85 3	75 3	100 4	125 4	75 3	75 4	60 3	65 4	50 3
1400	75 1	75	75 2	75 2	60 3	100 4	125 4	75 3	60 3	60 3	50 3	50 3
1600	60	75	75 2	75 2	60 3	100 4	100 3	75 3	60 3	60 3	50 3	50 3
1800	60	50	50	75 2	60 3	75 4	100 3	60 2	60 3	50 2	40 3	50 3
2000	60	50	50	50 1	50 1	75 4	75 2	60 2	40 1	50 2	40 3	40 3

Legend:

M1-Matthews Cartridge Type C.T.S.
M2-Matthews Fuse Link Series 50H and 100H below 100 amps. Series 100B above 100 amps
GE1-Gen. Elec. Cartridge Catalog 9F13A
GE2-Gen. Elec. Fuse Links Type 9F1S
LM-Line Material Unifit (Cartridge and Link)
SS1-Southern States Cartridge Type S.F.L.
SS2-Southern States Cartridge Type S.X.L.
K-Kearney "Tubular" Cartridge
SC1-Schweitzer & Conrad Silver Cart. Type SSI
SC2-Schweitzer & Conrad Tin Cart. Type STI
SC3-Schweitzer & Conrad Tin Link Series 88,000
B-Bussman Type JLS Cartridge or JPX Link

*
1 35 Amp Circuit Breaker quick-lag or Heineman magnetic
2 60 Amp Fuse
3 35 Amp Fuseton
4 50 Amp Multi-breaker

Table III Protection Afforded by Internal Secondary Breaker on One Type of Transformer so Equipped (Based on A.S.A. Permissible Emergency Overload and Manufacturer's Curves on the Internal Breaker)

Transformer Size and Type of Connection	Maximum Service Distance #8	#6	#4	Will Coordinate with Following at Minimum Service Distance of 100 Feet (1)
$1\frac{1}{2}$ KVA 2 wire	860	1340		20 Amp Fusestat, 30 amp Fuse, 20 Amp Breaker (2)
$1\frac{1}{2}$ KVA 3 wire	1870	over 2000		20 Amp Fusestat, 30 amp Fuse
3 KVA 3 wire		1250	2000	30 Amp Fusestat, 30 amp Fuse 35 Amp Breaker (2), 60 amp Fuse
5 KVA 3 wire		670	1040	35 Amp Circuit Breaker (2) 60 amp Fuse 35 Amp Fusetron, 50 amp Multi-breaker
$7\frac{1}{2}$ KVA 3 wire		670	1130	35 Amp Circuit Breaker (2), 60 amp Fuse 35 Amp Fusetron, 50 amp Multi-breaker

(1) Will not coordinate with other device if such device has greater time delay than those indicated.

(2) The circuit breaker is a Westinghouse "Quick Lag" or a Heinemann magnetic or equivalent.

Table IV

Maximum Service Distance in Feet for Which Transformer
May be Protected Against Secondary Short Circuits.
Transformer Impedance = 3.5%

7200 Volt Transformer Rating, KVA	$1\frac{1}{2}$ (2 wire)		$1\frac{1}{2}$(3 wire)		3(3 wire)		5 (3 wire)		$7\frac{1}{2}$ (3 wire)		10 (3 wire)
REA Recommended primary fuse rating, amperes	2		2		2		3		5		5
Conductor Size	#8	#6	#8	#6	#6	#4	#6	#4	#6	#4	#4
Fuse Make											
1. General Electric Type 9F1C	60	150	0	0	280	430	160	250	130	200	270
2. Schweitzer & Conrad 64,000 Series	0	0	0	0	60	95	150	230	70	110	210
3. Matthews 100H	0	0	0	0	200	320	170	270	130	210	260
4. Kearney Type QA	180	280	70	120	420	640	360	550	140	220	280
5. Kearney Type 200	0	0	0	0	40	60	60	90	0	0	90
6. Westinghouse Type U T	0	0	0	0	0	0	0	0	0	0	20
7. Line Material Unifit	0	0	0	0	0	0	60	90	90	140	210
8. Southern States Type F or AF		0	0	0	0	0	0	0	0	0	210
9. Railway & Industrial Eng. Type P. T.	70	170	20	30	290	450	210	320	90	140	190

point of the low voltage winding, and the ground sides of the arrester and primary winding at the same voltage level, these points are interconnected together on multi-grounded REA systems (except in California) and also connected to the lightning arrester ground and the system neutral. The surge voltage stress on the transformer insulation is therefore practically independent of the ground resistance, and dependent only on the characteristics of the protective device and the lightning surge. The system manager should maintain such ground connections and the interconnections, since the life of the transformer will depend on them. An additional consideration is the adequate grounding of the case for safety reasons.

Although, as stated above, the resistance of the arrester ground has little effect on transformer protection if the interconnection scheme is used, this does not mean that the ground resistance is unimportant. If the resistance to ground of the arrester ground lead becomes high, the voltage on the tank will rise to a high level upon discharge of the arrester current through the ground resistance. Due to the interconnection of the secondary winding, this will in turn be impressed on the consumer's wiring. Such high voltages may be injurious. It is therefore very important that the individual lightning arrester ground and the service ground at the consumer's service entrance have as low resistance as possible. Considering the service entrance equipment and the consumer's premises, the ground at the consumer's premises is the most important, but it is the individual ground at the transformer nearest the consumer which is next in importance rather than the combined interconnected system neutral ground.

VIII Maintenance of Transformers

Transformers, like all other electrical equipment, must be maintained. (7) The amount of maintenance depends on the investment in the equipment and the importance of uninterrupted service. Substation transformers, in particular, should receive special attention, while transformers which serve important loads also require frequent inspection. Small distribution transformers, serving relatively unimportant loads, however, cannot receive a great deal of maintenance, due to the excessive costs which would be required by such a procedure. The usual practice with regard to such small transformers is to bring a transformer into the shop and provide a thorough check when a change in transformer installation is made.

The following concerns particularly maintenance of substation transformers, and, in lesser degree, and where practical, other transformers.

A. General Inspection

1. Once a day, if possible, and at least once a week.

   a. Oil level. See if oil is up to required level.

b. Ambient temperature. A record should be kept of ambient temperatures.

c. Oil temperatures. A record of the oil temperature, particularly at peak demand, should be kept and coordinated with the ambient temperature. Some transformers have a load indicator instead of an oil temperature indicator in which case this reading should be made.

If it is impossible to take the temperature readings each day, the day of peak demand should be selected.

d. Coil temperature. Some of the larger transformers have thermocouples embedded in the coils to indicate coil temperature. This temperature should be recorded periodically, particularly at peak load.

2. Once a week, if possible, and at least once a month.

a. Load current.

Check current in each phase by means of a clamp-on ammeter, or using an ammeter with current transformers, if such are installed, for load on transformers and phase balance of transformers and feeders. Make check during peak load period and on or near day of maximum demand.

b. Voltage. Check voltage on each phase. It may be possible to eliminate over-excitation and excessive core loss by readjusting the tap connections. If a spare recording voltmeter is available, it is well to obtain a record of the voltage over a period of several days.

B. <u>Unit Inspection</u>

1. <u>Quarterly</u>

a. Ground resistance. The ground resistance at an REA type substation is very important due to the multi-grounded line construction. The operation of the arresters and the safety of the station depend on the grounding resistance. The ground resistance will vary with location and season of the year, and no hard and fast rules applicable to all cases can be laid down. In general, the resistance should be under 5 ohms, if at all possible. Ground connections to arresters, transformer tanks, bushings, fence and grounding devices should be thoroughly checked.

b. Oil tests. Manufacturer's instruction books and bulletins give methods for obtaining oil samples. Such instructions should be followed exactly, as many errors in oil tests are due to improper sampling. It is particularly important that the container be <u>clean</u> and <u>dry</u> and that the oil be taken properly. The oil sample should be tested by the manufacturer or by a laboratory. Oil testing to high insulation value does not necessarily indicate satisfactory conditions, as water may appear in the open type transformers under certain conditions, and not show up in the oil tests. It is therefore necessary to make the under cover and core checks as described below.

c. Lightning arresters and gaps. Check condition and settings of arresters and gaps.

d. Breathers. See if breathers are open and operating properly.

2. <u>Semi-annually</u>

a. Inspection under the cover. Inspection under the main cover, the manhole cover, and bushing supports should be made on an open type transformer to determine whether or not water condensation is taking place. During the initial period of operation, this should be done frequently, (approximately monthly) and after some operation, such inspection should be made at least semi-annually. If there is condensation, the manufacturer should be contacted for recommendations.

The condition of any disturbed gaskets should be checked to see if a new gasket is needed before re-assembly. It is usually preferable to install a new gasket than to take a chance on an old one.

3. <u>Biennially</u> (every two years).

a. Inspection above the core. On open type transformers, the oil should be drawn down to the top of the core, and all parts inspected for condensation and sludge about every two years.

b. Oil filtering. The dielectric strength of the oil in an open type transformer must be maintained. If the oil test shows a dielectric strength of not more than 16 to 17 KV for the one-tenth inch gap, the oil should be filtered. A dielectric strength above this is adequate, providing there is no local condensation. On oil conservator or gas seal transformers, oil filtering is rarely necessary.

c. Transformer and Refinishing. The transformer finish should be inspected and any badly worn spots should be repainted, or the entire tank should be refinished. The most important step in such work is to thoroughly prepare the surface by removing all loose paint, blisters, scale, and rust; and in some cases all the old paint should be removed. After cleaning, the tank should be painted as soon as possible. Recommendations on type of paint and primer, number of coats, etc. should be obtained from the transformer manufacturer.

C. Detailed Inspection

An overall inspection should be made about every four or five years. If deposits of sludge are found, the interior of the transformer should be raised from the tank and thoroughly washed with new oil. All parts should be examined for displacement, tight connections, etc., and the tank should be cleaned. If the sludging seems to be excessive, the matter should be called to the attention of the manufacturer. Most rural systems will necessarily have to rotate the spare transformer so that one transformer can be inspected each year, until complete round is made. If no spare is available, it might be possible to use the open-delta or Vee connection described above during periods of light load.

D. Unenergized Units

Where transformers hang on the line unenergized for long periods, the underside of the cover and visible parts should be checked for moisture, and oil samples should be taken before energizing. If moisture is present, recommendations should be obtained from the manufacturer before energizing the transformers.

APPENDIX

Wye/Wye Transformer Banks

A. Advantages and Disadvantages

This type of transformer bank is seldom used in substations design in the United States. There are, however certain features about the wye/wye type bank which are of interest, yet are not generally known. A resume of these features may be useful in explaining the limited use of the connection or in suggesting its use for some applications to which it may be particularly suited.

The wye/wye connection is the most economical connection for low power transformers of high voltage ratings since it requires a minimum of turns and coil insulation per phase because of the fact that the voltage across each winding is only $1/\sqrt{3}$ times the line-to-line voltage. In addition since each winding carries the full phase current the conductors must have larger cross sections than the delta connected transformer. This increased conductor size results in a larger capacitance between turns and reduces surge voltage between windings due to lightning and other transients. If one phase of a wye/wye connected bank develops a fault the remaining two phases can still be served, although the total bank capacity in such a case will be only 58 percent of its three phase capacity. In case such operation is attempted with a single-unit 3 phase transformer both the primary and secondary of the faulted phase must be disconnected from the remaining two phases and the sound winding of the faulted phase short circuited. Where three single-phase transformers are used it is only necessary to disconnect the faulted transformer and remove it. The remaining two transformers will operate without any connection changes. The wye/wye connection is extremely useful in the parallel operation of transformers with unequal impedances or voltage ratios, since in contrast to the delta/wye connection these conditions cause only negligible load unbalance and circulating current.

The above advantages of the wye/wye bank are however outweighed for most uses on rural systems by the following disadvantages:

1. Emergency three-phase service cannot be rendered when one unit of a bank fails as can be done on a delta/wye bank.

2. Third harmonic voltages amounting to as high as 30 to 60 percent of the fundamental may be present at normal flux densities in the case of either the single-unit three-phase shell type

transformer or the three single-phase units. The harmonic voltages on the single-unit three-phase core type transformer are, however, only about 5 percent of the fundamental and this transformer can therefore be operated successfully in a wye/wye bank without causing either telephone interference or reducing its rating at the fundamental frequency, as long as the source of supply is free of harmonics.

3. Third harmonics from the generators flowing in the neutral wire cause additional telephone interference. On the other hand, both generator and primary neutral must be interconnected to allow unbalanced four-wire supply.

B. Use of Wye/wye Banks in the Operation of Parallel Networks.

Assume a system similar to that shown in Figure 12. In this system networks CE and DF are operated in

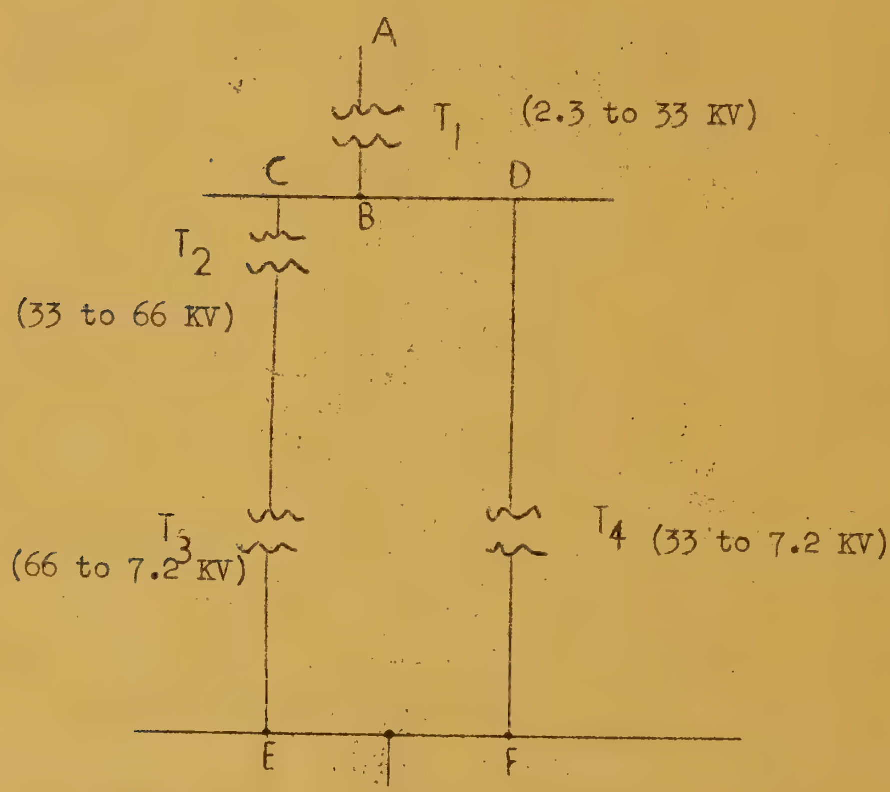


FIG. 12

parallel, both being fed by a 33 Kv bus at CD and both feeding into a 7.2 Kv bus, EF at the terminal. However, network CE contains one more transformation than does network DF.

In such a system it is impossible to operate all three banks (T_2, T_3 and T_4) in delta/wye. A study of the voltage vector relationships will show that it is impossible to operate such a system with T_2, T_3 and T_4 all connected delta/wye. One of these banks must be connected wye/wye in order to prevent a 30 degree phase shift from existing between points E and F. If for example the banks were connected as in Fig. 13, parallel operation would be impossible due to the phase shift. Figure 14 shows one of the possible correct connections.

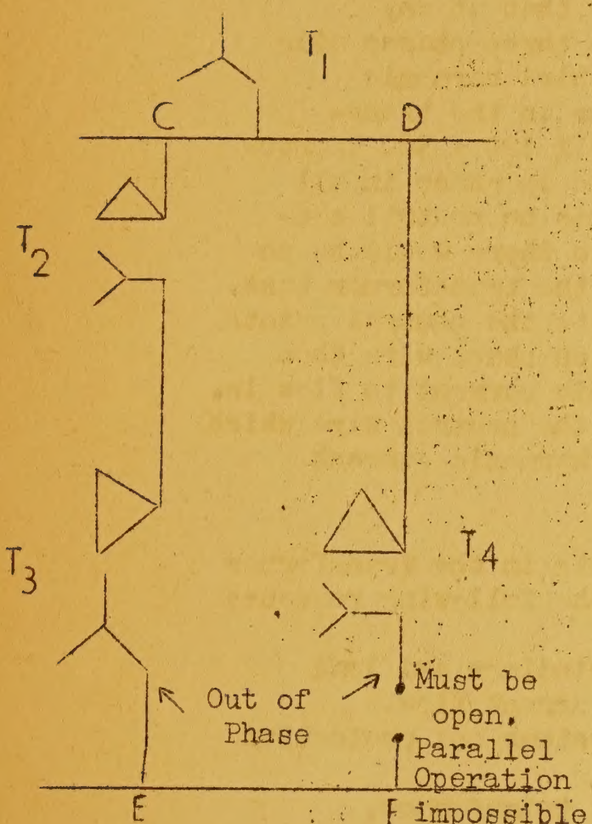


FIG. 13

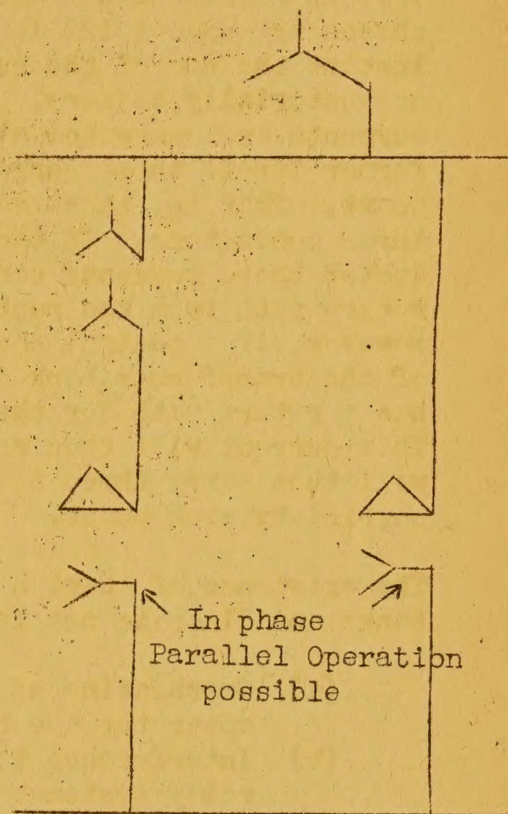


FIG. 14

C. Unbalanced Loading of Wye/wye Banks.

On three phase systems using wye/wye transformer banks it is possible to operate with unbalanced loading of the phases only if both load and supply side of the bank are four-wire systems similar to the multi-grounded neutral REA type lines. Otherwise the unbalanced loading causes a shift of the neutral point which would then result in unbalanced voltages on the various phases. With multi-grounded neutral lines on both supply and load sides and the transformer bank neutrals grounded on both

sides each phase of the bank can be loaded to its full capacity without any regard to the loadings on the other transformers in the bank and no abnormal voltages will result. In fact it is possible to operate such a bank with three transformers of different capacity and impedance ratings without causing circulating currents or unbalance. This is particularly advantageous when the three phase system is used to supply single phase loads which cannot be balanced easily and continuously between phases.

D. <u>Harmonic Voltages and Currents in Wye/wye Banks.</u>

In symmetrical three-phase wye connected systems the vectors representing voltages or currents in the various phases are spaced 120 degrees apart so that at any instant the sum of the currents in the three phases adds up vectorially to zero. However, if third harmonic currents are generated at the source or in the transformer itself these currents will be 3 X 120 = 360 degrees apart. That is, these currents will be in phase in all three conductors. If the wye system has no neutral conductor these currents cannot flow since there would be no return path from the neutral point of the transformer bank. However, if a neutral conductor connects the neutral points of the transformer bank and source, each phase wire then has a return path for the third harmonic current to flow in. This current will then return through the neutral wire which will thus carry three times the third harmonic current carried by each phase.

The existence of third harmonic currents in the transformer banks and lines is not desirable for the following reasons:

(a) Overheating of transformer windings and load apparatus due to increased current flow.
(b) Interference to telephone systems and protective relay systems.
(c) Increased core losses in the transformer.

It should be noted that even when third harmonic currents cannot flow in the line because of the lack of a neutral conductor, third harmonic voltages from line-to-ground can still appear. Such voltages may result in:

(a) Increased insulation stress
(b) Telephone interference by electrostatic induction in the telephone line.
(c) Possibility of resonance phenomena at third harmonic frequencies.

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